THE EMR SMALL-SCALE FLAME TEST

by

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ABSTRACT

The small-scale flame test used by EMR since 1957 for certification of fire-resistant conveyor belting has been critically re-examined. Some improvements in the apparatus and clarifications of the procedure are recommended. A summary of the certification experience with this test is given. One important conclusion is that the proposed elimination of the 'flowing air' component of the test would allow the passing of unacceptable belting. The tolerances required for the various parameters of the test have been estimated by a detailed study on one particular belting. These tolerances have been incorporated into the CSA draft standard on fire-retardant conveyor belting.

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ESSAI À LA FLAMME SUR UNE PETITE ÉCHELLE -EMR

par

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RÉSUMÉ

L'essai à la flamme sur un petite échelle que CANMET utilise depuis 1957 pour homologuer les courroies transporteuses ignifugées a sérieusement été réexaminé. On recommande que des améliorations soient apportées à l'appareil et que des explications soient fournies relativement au fonctionnement de l'appareil. Le présent rapport présente les résultats de l'essai pour fins d'homologation. Une des conclusions importantes tirée de ces résultats est que l'élimination de l'élément 'courant d'air' permettrait la certification de courroies transporteuses qui ne répondent pas aux normes. Une étude détaillée portant sur une courroie en particulier a été effectuée afin de déterminer les écarts admissibles que doivent comprendre les différents paramètres utilisés pour les besoins de l'essai. Ces exigences ont été incluses dans la norme de l'ACNOR s'appliquant aux courroies transporteuses ignifugées.

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INTRODUCTION

A Canadian Standards Association (CSA) Technical committee is in the final stages of preparing the first edition of a standard on fire-retardant conveyor belting. The Committee decided to include the existing EMR small-scale flame test in this standard. This test was originally copied from that used by the U.S.A. regulatory agency responsible for underground mines, but has undergone some modifications since its inception in 1957.

The documentation on this test seems to be rather scanty. Because the test has been adopted by the CSA Technical Committee, it seems appropriate at this time to review its details and to put it into a form suitable for a standard. Specifically, the purposes of this report are:

(a) to present the history of the experience with this test at EMR;
(b) to discuss the details of the method currently used and its shortcomings;
(c) to propose improvements based on experiments reported herein; and
(d) to determine the effects of various parameters on the results obtained.

HISTORY OF THE TEST

The description of the original apparatus and method was given in "Certification Memorandum No. 2" (1). The purpose of this test was to determine how long it took for flame and glow to disappear from the sample after it had been immersed for 1 min in the flame of a Bunsen burner. The maximum allowed times were 1 min for flame and 3 min for glow. The salient features of the procedure were:

(a) the flame to be blue and 3 inches high with its temperature 1 inch above the burner to be 899 ± 28°C,
(b) the sample to be clamped at one end, giving an unsupported length of about 130 mm,
(c) the sample to be exposed to flowing air of velocity 1.5 m/s immediately after the burner had been removed.

The description of the test is identical to that given in the U.S. regulations (2), except that the temperature of the flame is not specified in the latter. It must also be noted that an ASTM Standard exists (3), which is virtually identical to the U.S. Government standard but specifies that the

flame shall be 760 ± 55°C. Recently (4), the U.S. Mine Safety and Health Administration (MSHA) has published a more detailed description of the test specified in (2). Although the temperature of the flame is still not specified, the flame is described as having "no distinct inner cone". This is distinctly at variance with the CEAL practice (for which the author has been unable to find any documentation) in which there is an inner cone about 25 mm high. This explains the difference in temperature between CEAL and the ASTM Standard. The details of measuring the flame temperature are given in the Appendix.

The positioning of the flame with respect to the sample is illustrated in Fig. 1. It should be noted that once the burner type, the size of the inner cone and the temperature have been defined, the flame is fully defined, and that aspect of the test should not be subject to variance. The flow of methane required is about 3.8 L/min.

The draft of the New South Wales (Australia) specifications on fire-resistant conveyor belting contains a similar small-scale flame test. The only differences appear to be that propane is used, an inner flame of 25 mm height is specified and the required temperature of the flame is 1000 ± 100°C.

In 1962, the severity of the certification test at CEAL was increased by requiring that the product undergo an additional 'still air' test (5). This still air test was exactly the same as the original test (now referred to as the 'flowing air' test) except that the fan to create the airstream is not turned on.

A problem with a long sample clamped at one end is that it tends to droop, especially when heated. To eliminate that problem, a sample holder was designed so that the sample rested on a stainless steel angle, with only 25 mm projecting beyond the support. (This device also had the advantage of making the test easier to perform, and making the results more reproducible.) It is not known when this modification was introduced but is believed to have been more than 3 years ago. The current certification booklet (5) does not contain any reference to this modification.

CERTIFICATION EXPERIENCE WITH THE FLAME TEST

The information contained in this section is based on a survey of the CEAL certification files. Although the survey was carried out conscien-

tiously, it is possible that the author missed some files. It is unlikely that more than 5% were missed.

The total number of products tested to the end of 1983 was 352. Figure 2 shows the distribution of the tests over the years. The reason for the fluctuations are due to several reasons: (1) 'An induction period' for the EMR certification service to be accepted; (2) Technological developments in the manufacture of conveyor belting; (3) Different companies entering into the Canadian marketplace. After the Canadian Standard has been published, it is anticipated that the acceptance of the CEAL certification service will grow. Also the Standard is more rigorous than the current specifications, thus requiring manufacturers to do more work to develop more products.

It is interesting to examine statistics on submitted samples that have failed the flame tests:

	No. failed	
Still air:		
excessive flameout time	51	
excessive afterglow time	4	
Flowing air:		
excessive flameout time	0	
excessive afterglow time	20	
total	75	(21%)

The usual procedure is to do the still air tests first; if the product fails, then the flowing air tests might not be carried out. Hence, it is possible that if the order of tests were reversed, the number of samples rejected by the flowing air test may have been greater.

The still air test is obviously more severe for the flameout. On the other hand, for afterglow, the flowing air test is clearly more severe than the still air. Hence, if afterglow is of interest, the flowing air test should not be eliminated, as has been proposed in the draft of the CSA Standard.

The draft of the CSA Standard also reduces the maximum allowed flameout time for type A belting (the type intended for use in gassy mines) to 40 s and the maximum allowed afterglow time to 120 s. If these criteria had been applied to the certification tests discussed above, the former modification

would have caused the additional failure of another 18 products; the latter modification would have caused the additional failure of only one product.

PROBLEMS WITH THE PRESENT PROCEDURE

The problem with the sample holder that has been in use the past several years became apparent recently when a certified conveyor belting that had been coated so as to extend its life was submitted for re-certification. The mean flameout time in still air was 37 s, less than the maximum 60 s allowed. There was no afterglow observed. However, it was noted that, when lit in free air with a match, the entire coating would quickly catch fire! Careful observation of the flame test showed that the sample holder acted as a heat sink and would not permit the flames to travel beyond the unsupported section of the sample. When the original type of sample holder was used (the type still in use at the U.S.A. Mine Safety and Health Administration (MSHA)), the entire length of sample burned.

To eliminate this problem while maintaining the positive features of the CEAL sample holder, a new holder was designed (see Fig. 3). The author proposes that an additional criterion be added to the test: the product fails if the damaged portion reaches the sample support. The rationale is that amount of spread of flame is adequate indication of propagation. This criterion removes what the author considers a logical shortcoming of the flame test: if a sample is highly flammable, it will be completely consumed within 60 s and will thus have zero flameout and zero afterglow times.

Still air tests were carried out on 2 conveyor beltings, one PVC and one rubber with asymmetric sides:

	Flameout time(s)		Length burnt(mm)
	old holder	new holder	new holder
PVC	--	27 ± 13	28 ± 3
Rubber			
thick side	--	34 ± 14	27 ± 3
thin side	37 ± 27	75 ± 13	29 ± 4

Notice that in the last line of the table, the product would have passed with the old holder, but would have failed with the new one. With the old holder, only 25 mm of the sample can burn before the sample holder quenches the flame. The effect of a relatively small additional length available to burn can have a substantial effect on the flameout time.

The question can be asked: How many false passes could have been made with the old sample holder? Unfortunately, that question cannot be answered without complete retesting. When the CSA Standard is adopted, products will have to be retested anyway; at that time, the new sample holder will be used for the small-scale flame test.

Another major problem that has come to light recently is the present requirement that only the pulley (normally the thin) side is tested. The justification for this was that the pulley side would most likely be the side exposed to any flame. In practice, however, the user may reverse the belt in order to get more usage out of it. In the example above, the thin side is the more flammable side. This is not always the case, particularly if the two covers are not made from the same material. The CSA Technical Committee has addressed that problem by requiring that both sides of the product must be tested.

PARAMETERS OF THE TEST

The tests described in this section were carried out before the new sample holder had been constructed. The belting used (a PVC type) did not burn to the extent where the sample holder would have an effect. The parameters studied were: (a) temperature of the flame; (b) flame height; (c) duration of application of the flame; (d) width of the sample; (e) length of sample beyond the wire gauze; (f) drying of the sample. The purpose was to determine how much scatter would be caused by normal variation in carrying out these tests. The parameters were varied one at a time; because the effects were not great, there was no attempt made to examine second order effects. The standard conditions were: temperature 900°C, flame height 25 mm, duration 60 s, width 12 mm, exposed length 12 mm, and unconditioned (i.e., the samples tested as received, not dried).

The flameout times are given in Table 1, along with the means and standard deviations for each set. As can be seen from the great scatter of

data, it is difficult to determine small differences between different sets. The percentage losses of the original total weight of the sample are given; notice that the standard deviations (expressed as a percentage of the mean values) are quite small, in marked contrast to flameout standard deviations. The temperature of the flame appears to have a significant effect, with the flameout times increasing with temperature as would be expected. The length of the sample exposed to the flame does not seem to have much effect on the flameout times, but does increase the weight loss. The width of the sample seems to have a strong inverse effect. Possibly this may be due to the narrower widths having relatively larger surface areas of carcass (which is more flammable) exposed to the flame. The effects of drying the samples and of the time that the burner is on do not seem to have too great an effect. Increasing the flame height to 30 mm seems to increase the flameout times and weight loss. It should be noted, however, that the temperature at 25 mm height was kept at 900°C, and therefore the flame with 30 mm height would actually have been hotter at its maximum temperature (just above the inner cone).

The data in Table 1 were used to derive the following tolerances for use in the draft of the CSA Standard: temperature ± 20°C, height ± 1 mm, width ± 1 mm, length ± 1 mm, time ± 1 s. These tolerances will keep variations in these parameters from affecting the flameout times by more than the intrinsic standard deviations. These tolerances will not be difficult to achieve by any reasonably conscientious tester. It is realized that flameout times of different products may vary differently with these parameters, but, except for samples which are nearly completely consumed by the applied flame, use of the tolerances above should not cause any significant error.

DISCUSSION

The large variance of flameout times within a given sample is most striking. This does not appear to be in general due to inhomogeneity of the product, variation of the testing conditions or external changes. Furthermore, the values do not follow a normal distribution, which has the unfortunate effect of making it impossible to apply the usual statistical tests. In fact, the distributions seem to be bi-, or possibly multi-modal. The following explanation is proposed: propagation of the flame can be regarded as a critical phenomenon, a small variation in the parameters of which, will cause

the condition to be either critical or not critical. If the latter, the flame may go out immediately, if the former, the sample may burn for, say, an additional 30 s.

The scatter of the afterglow times is usually much greater than for the flameout times. Again, the best interpretation would seem to be the critical condition approach: if a particle has begun to glow, it will glow for some period. The conditions for a particle to begin glowing are random, based on the geometrical location relative to the air stream, the amount of combustion in its vicinity and the physical and chemical variations.

The main reasons for the inclusion of the small-scale flame test in the new CSA standard seem to be the fact that it has been around a long time and that it is relatively simple to perform. Although it will screen out many poorly fire-retardant products, the correlation with larger-scale tests, such as the propane gallery test, would not be expected to be good, simply because the size of sample is so small. Different mechanisms of flame propagation occur, depending on the size of sample. Moreover, the small-scale flame test is primarily one of flame extinction, rather than propagation. In virtually all cases, the flowing air in the flame test just acts to blow out the flame, whereas in the propane gallery test, it is the primary cause of the spread of the flames.

It has been suggested that the small-scale flame test be used for quality control. Unfortunately, it is not very useful because of its large intrinsic scatter. A product would have to change a great deal in order to be able to demonstrate that it is different on the basis of this test. The fact that one cannot use statistics based on the normal distribution is a further impediment. The oxygen index test would be a much more useful test for quality control (6).

In order to bring more reliability to this test, a round-robin testing program on conveyor belting between EMR and MSHA has begun. Upon successful completion of this program, it would be recommended that manufacturers who use this test should participate in a similar program, as well as regulatory agencies who use a similar small-scale flame test.

CONCLUSIONS

1. By its very nature, the small-scale flame test cannot yield even moderately precise values for flameout and afterglow times.
2. It is recommended on the basis of EMR's experience with this test to not eliminate the flowing air test.

REFERENCES

1. Brown, G.K. "Certification of fire-resistant conveyor belting for use in mines", Certification Memorandum No. 2, Energy, Mines and Resources Canada; Dec. 1957.

2. U.S.A. Code of Federal Regulations, Title 30, Part 18, Section 18.65.

3. American Society for Testing Materials, "Rubber belting, flat type", Section 13, D378-77.

4. "MSHA standard flame test procedures for conveyor belt, hose and other materials", MSHA, 1981.

5. Bossert, J.A. "Certification services for underground mining equipment and materials", CANMET, Division Report ERP/MRL 80-21(TR).

6. Mintz, K.J. "Procedure for oxygen index tests at the Canadian Explosive Atmospheres Laboratory", CANMET, Division Report ERP/MRL 83-46(TR).

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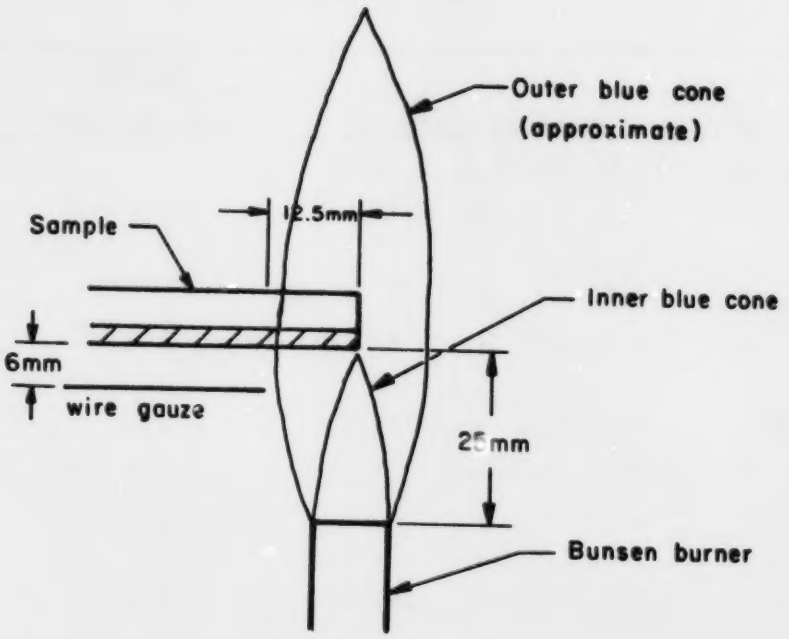
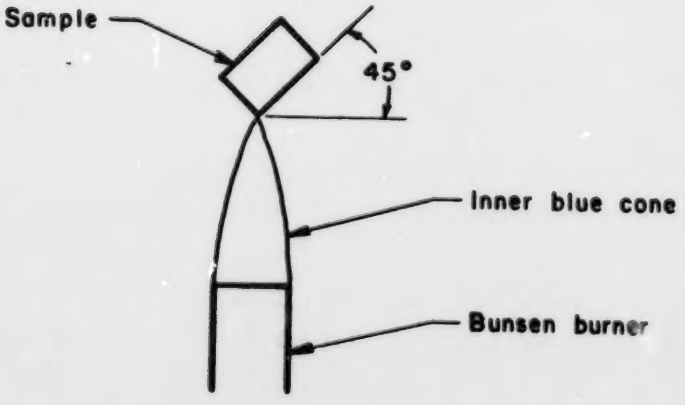
Table 1 - Flame test data

Conditions	Flameout times (s)	Mean & std. dev. (s)	% weight loss
Standard	3.0, 3.2, 1.0, 1.5, 10., 2.5, 3.3, 1.1, 2.7, 1.1	2.9 ± 2.6	1.8 ± 0.2
Height =20 mm	3.7, 2.6, 2.2, 1.8, 5.1, 6.0, 1.9, 3.3, 3.4, 1.6	3.2 ± 1.5	1.9 ± 0.2
Height =30 mm	4.0, 3.1, 2.1, 2.7, 5.0, 10.6, 5.3, 2.6, 4.2, 4.6	4.4 ± 2.4	2.4 ± 0.2
Temp. =800°C	1.6, 1.5, 0.0, 1.4, 3.7, 1.6, 1.2, 1.1, 0.9, 2.0	1.5 ± 0.9	1.7 ± 0.1
Temp. =1000°C	4.2, 4.7, 4.3, 4.0, 6.1, 3.4, 3.9, 3.0, 4.4, 8.0	4.6 ± 1.5	2.6 ± 0.2
Length =8 mm	1.4, 7.9, 1.4, 0.0, 1.2, 3.0, 1.4, 0.0, 4.7, 3.7	2.5 ± 2.4	1.5 ± 0.1
Length =16 mm	4.9, 1.4, 3.0, 4.0, 1.8, 1.4, 1.6, 4.8, 3.7, 1.2	2.8 ± 1.5	2.3 ± 0.2
Width =7 mm	3.5, 8.2, 20.9, 8.4, 2.6, 5.7, 3.0, 1.2, 1.5, 4.5	6.0 ± 5.8	3.4 ± 0.3
Width =16 mm	1.7, 4.1, 3.7, 4.2, 1.5, 1.2, 3.8, 4.0, 1.0, 1.0	2.6 ± 1.4	1.7 ± 0.2
Time =50 s	1.1, 8.5, 3.4, 2.8, 1.5, 1.3, 1.6, 3.5, 3.4, 1.2	2.8 ± 2.2	1.6 ± 0.1
Samples dried	5.0, 3.6, 3.3, 4.2, 2.1, 6.0, 1.1	3.6 ± 1.7	1.9 ± 0.1



Side View



End View

Fig. 1 - Position of flame

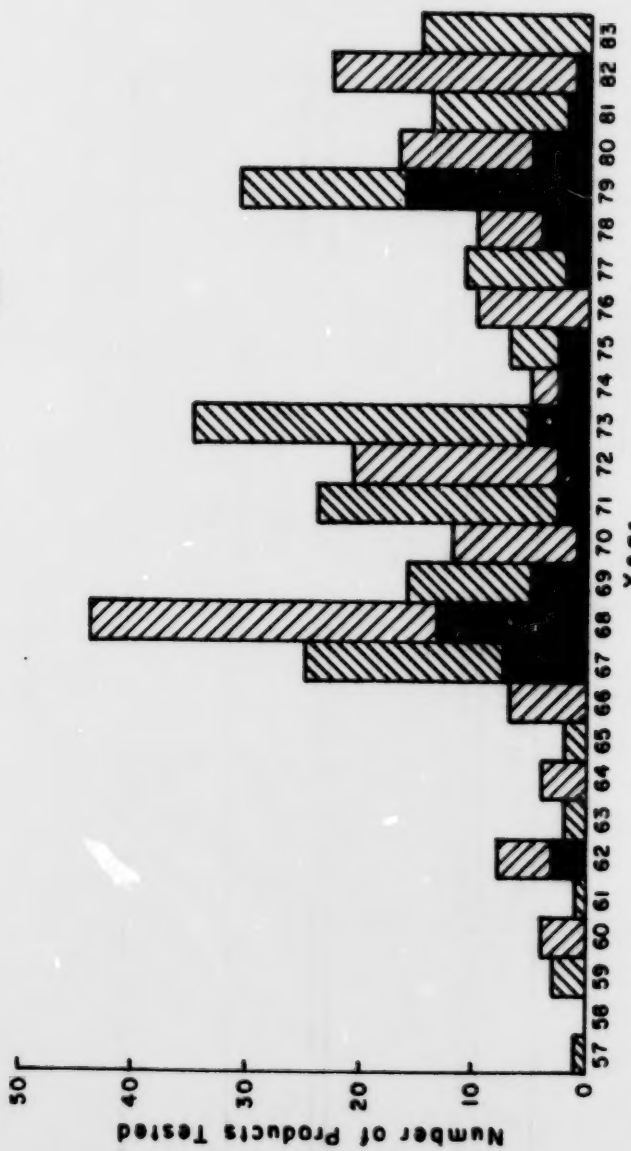
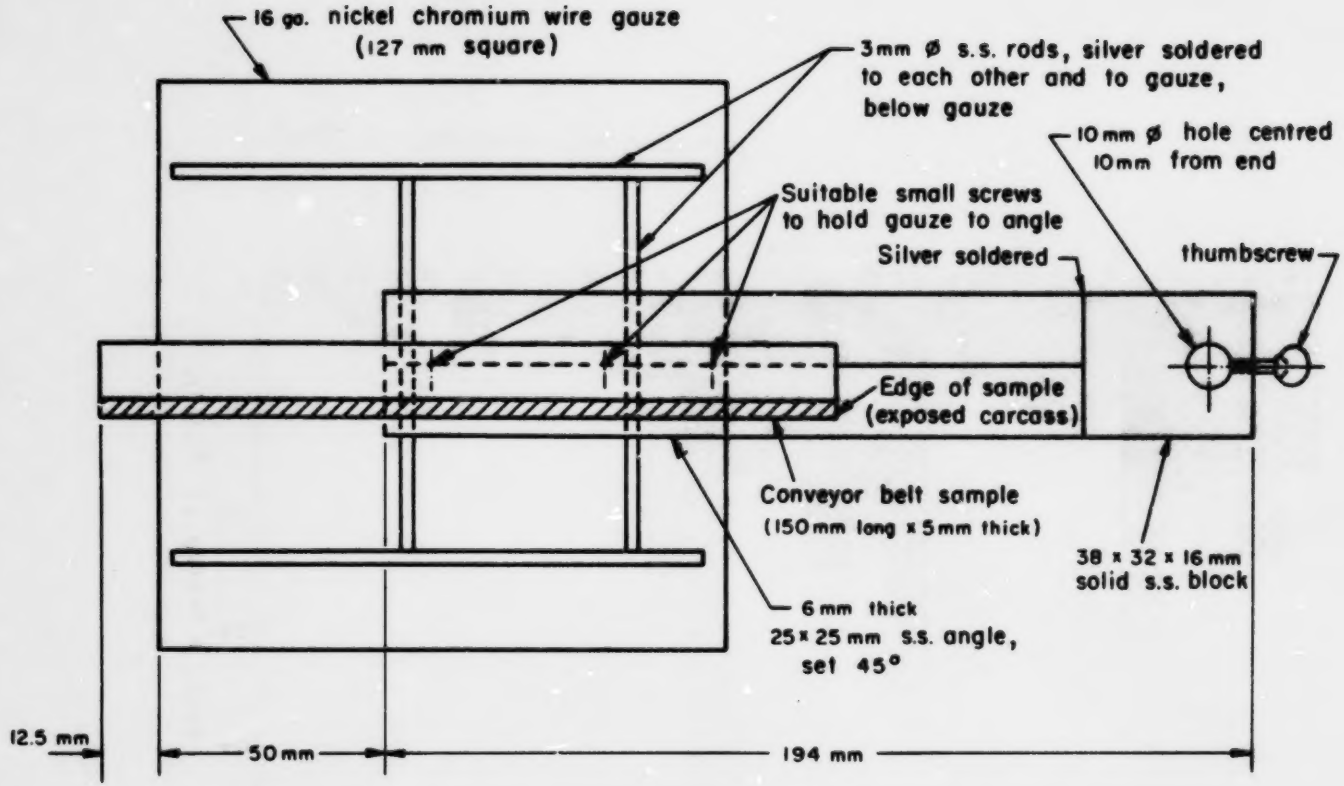


Fig. 2 - Certification test history



Top View

Fig. 3 - New sample holder

APPENDIX

MEASUREMENT OF FLAME TEMPERATURE

The EMR test has specified 'a no. 14 B&S gauge, chromel alumel thermocouple', since 1969(A-2). Previous to that, only 'a suitable thermocouple' was specified(A-1). The flame temperature mentioned in this report refer to the thermocouple mentioned above. It is important to note that these temperatures are not the 'true' flame temperatures. Using a fine gauge thermocouple supplied by MSHA, the temperature measured at the tip of the inner cone was 1090°C (when the EMR standard thermocouple read 900°C). The maximum temperature in the flame was 1110°C, which occurs at about 10 mm above the tip of the inner cone. The existing thermocouple reads low probably mainly because of its size: it is sufficiently large to withdraw a significant amount of heat and also physically to disturb the flame itself. Despite the fact that it does not give the 'true' temperature, it has the advantages of being reproducible and requiring little operator attention. Most importantly it does define the flame quite precisely.

The Australian Standard referred to in the text specifies 1000 ± 100°C as the flame temperature at the tip of the flame. Hence, the EMR flame is within the tolerance of the Australian test.

For the MSHA-type flame, the temperature measured at 25 mm above the burner varied considerably through the flame, from 750°C at the centre, to about 1000°C at the outer edge of the flame. (By contrast, the EMR flame temperature remained virtually constant across the flame.) It would appear that the ASTM Standard implies that a thin gauge thermocouple should be used and the measurement taken in the centre of the flame, which is not the maximum temperature. Specifying the temperature of the MSHA-type flame does not appear to be too practical because of its spatial distribution.

REFERENCES

1. G.K. Brown, "Certification of fire-resistant conveyor belting for use in mines", Mines Branch FRL 269; 1957

2. Op. cit., second edition, (Mines Branch Information Circular IC 215); 1969.